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The Effect of Various Pigments and Binders on Coated Gloss, Print Gloss, and Delta Gloss

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THE EFFECT OF VARIOUS PIGMENTS AND BINDERS ON COATED GLOSS, PRINT GLOSS, AND DELTA GLOSS

by

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ABSTRACT

The objective of this thesis is to determine the effects that various pigments and binders have on the coated gloss, print gloss, and delta gloss values. The effects of coat weight and calendering on the glossing response of the sheet will also be determined. Supplemental tests such as Parker Print Surf Roughness, brightness, and opacity will be measured to further evaluate the coating formulations.

A total of eight different coating formulations were made using four very common pigments and two latex binders. The four pigments used were #2 clay (100%), calcined clay (15% substitution), delaminated clay (25% substitution), and calcium carbonate (100%). The two latex binders used were styrene butadiene(SBR) and polyvinyl acetate (PVAC). Latex binders were chosen because their gloss response when applied in coatings is better than starch or protein binders. In order to isolate the effect of the pigment and binders a number of variables were held constant or within the same range. The solids levels of all coatings was adjusted to 62%. The binder ratio used was 12% based on dry parts pigment. The Brookfield viscosity was adjusted within the same range using polyacrylate. The printing ink and the print conditions were held constant also. The ink used was a low viscosity water based flexographic ink. A low gloss ink was chosen in order to eliminate the effects of the ink on the print gloss.

When pigments are used alone in coating formulations, their particle size has the most dramatic effect on the gloss response of the sheet. The finer particles create a more optically smooth sheet therefore giving higher gloss values. When binders are introduced into the sheet, the pigment to binder particle interaction also plays a major role.

A coat weight increase of 5 g/m^2 gave an average increase in coated gloss of 10% and gave a 20% increase in calendered gloss. The delaminated clay using the PVAC as the binder showed the highest gloss response due to an increase in coat weight. Calendering the sheet improved all gloss values. The effect was greater for coated gloss than for the print gloss. This was desired because it proves that the gloss of ink did not contribute to the print gloss but that it was the coating structure that affected the gloss response. The effect of pigment and binder type varied depending upon the combination used. The calcined clay gave the highest calendered gloss values which was not expected. However, when these samples were printed they displayed the highest delta gloss. This is due to the large particle size of the calcined clay. High delta gloss values are not desired because they produce a contrast between the image of the coating and the printed image. The pigment-binder interaction played a major role in determining the gloss response. When the PVAC binder was used, the delaminated clay gave the best gloss response with a delta gloss value of near zero (.2). When the SBR was used, the #2 clay gave the best response in gloss response. This was expected because the SBR latex is known for its high gloss response. A more detailed description and interpretation of the results can be found in the results and discussion section.

TABLE OF CONTENTS

INTRODUCTION

The demand for high quality coated paper has grown in recent years because of the large expansion in the volume of multicolor printing. The increase in production rate for printing and converting operations imposes a higher demand on the coated paper. The print quality of coated papers is one of the most important factors to the customer. The major reasons for pigmented coating are to improve the appearance of the sheet before and after printing. Before printing, the coating should improve brightness, gloss, smoothness, and other properties. After printing, the gloss of ink film (print gloss), freedom from mottle, detail of the image, and improvement of show through are achieved. The appearance of the coated sheet is generally the main factor in deciding the quality of the coating. Gloss and print gloss are very important properties both to the paper manufacturer and to the printer.

The gloss of a coating describes the optical smoothness of the surface and it varies with refractive and incidence angle. The gloss is a function of the microroughness of the surface of the sheet. The printability of paper may be defined as its ability to receive ink in the printing operation to produce an image of good quality. This depends on a number of things in other than the coating structure. Print gloss is a complex function of coating structure, printing conditions, types of ink, and the ink levels used. (1)

It is known that different pigments and binders affect the final sheet properties in different ways. Interactions between pigments and binders effect the particle packing in the coating formulation in various ways. A better understanding of what variables affect gloss and print gloss can determine what the coating formulation will be comprised of.

While there are literally millions of different coating formulations, the objective here is to isolate many of the variables in order to examine the contribution of certain pigments and binders to the gloss properties of the coated sheet.

Four very common pigments are going to be used in the coating formulation. They are #2 clay, delaminated clay, calcined clay, and calcium carbonate. The #2 clay and the calcium carbonate ($CaCO_3$) formulations will be made using 100% of this pigment type. The delaminated and calcined clays will be added as substitution for the #2 clay (in 25 and 15% ratios respectively). The two different binders used will be SBR (styrene-butadiene) and PVAC (polyvinyl acetate), which are both latex binders. These binders were chosen because latex binders are known to improve the gloss or at least not deter from gloss as starch binders are known to do. All the pigments and binders used are common to industry, this was done in order to make the thesis more applicable. Other variables such as solids content, binder addition level (binder ratio), low shear viscosity, pH, printing conditions, ink type, and ink levels were held constant or within the same range. This was done in order to isolate the effects that the pigments and binders had on the final sheet properties.

GOALS and OBJECTIVES

To start with, there were four main reasons why this thesis was attempted.

1) To determine which combination of pigment and binder gave the best coated gloss, print gloss, and delta gloss.

2) To examine the effects that coat weight has on the coated, print, and delta gloss.
3) To determine the effects that calendering had on the coated, print, and delta gloss of the different coating formulations.
4) To persuade other students to investigate further in this area in order to combine the departments of Paper and Printing and utilize both facilities.

All of these goals will be covered in the Results and Discussion section along with other findings and problems that were encountered.

BACKGROUND

The coated paper market has become increasingly competitive in recent years, forcing papermakers to strive for greater production efficiency and higher quality standards. These higher quality standards are largely driven by the demands of printers who want to increase their own productivity.(2) Pigmented coatings are widely used to improve the appearance and printability of paper. There are virtually millions of different coating formulations, but eight typical formulations will be studied here. Four pigments along with two different binders will be used to make up eight different formulations. The effects of these pigments and binders on gloss, print gloss, and delta gloss will be examined. The delta gloss is simply the numeric difference between the coated and print gloss. In order to give a general understanding of the different coating formulations, pigments, binders, gloss, coating rheology, and the CLC will be discussed independently.

PIGMENTS

A pigment is an inorganic mineral. Pigmented coatings are widely used to improve the appearance and printability of paper. Although there are many types of pigments, the focus of this study was to examine four very common ones. Three types of clays and one calcium carbonate pigment was used. The three clays used were the #2 clay, delaminated clay, and calcined clay. The percentage of particles finer than 2 microns serves as the best index of the gloss and opacity producing properties of the clay as a coating pigment. (3 p.77) It is the 'platiness' of the clay structure or percentage less than 2 microns which affects the gloss more than any other factor.

From source (4 Janes p. 39) it can be seen that the #2 clay has about 80-82% of its particles finer than 2 microns. The delaminated clay has any where from 80-??% finer than 2 microns. Delaminated clays are used in low weight coatings because they provide good fiber coverage, good smoothness, good print quality, and excellent resistance to discoloring during the supercalendering process.(5 p.103) Delaminated clays are used in combinations with other clays because of their severe rheological behavior. Delaminated clays are best known for improving smoothness and ink holdout. Calcined clay is produced by firing clays at extreme temperatures in excess of 800 degrees Celsius. This process greatly increases the brightness of the clay, but a disadvantage is that it increases the abrasiveness of the clay. Calcining the clay also sinters the finer particles together thus reducing the particle fineness (% less than 2 microns).(3 p.67) This in turn should lower the gloss of papers coated with this type of clay.

The calcium carbonate used was GCC or ground calcium carbonate. It is important to distinguish between the type of calcium carbonate used since there are many different kinds. The many different kinds will give inherently different end properties. The final properties are almost entirely dependent on the particles size. The fine GCC CaCO3 was used in which about 75% of the particles are less than 2 microns. This type of GCC is supposed to give high solids, high brightness, and good gloss. The rheology of GCC is not as limiting as that of most clays (6 p.40), which allows you to run at higher speeds. Along with particle size, particle size distribution is also of major importance when dealing with CaCO3. The size distribution within small ranges becomes important for best end results.(3 p.32)

The pigment particle reactions give rise to viscoelastic properties. When electrostatic interactions between suspended particles induce flocs or preferred arrangement of the particle at rest, the particle will have a tendency to return to that state.(7) The observed high elasticity of clay based coatings can be attributed to the strong interparticle interactions. Carbonate based coatings on the other hand, do not exhibit substantial elasticity probably due to the weak interparticle interactions. In addition to the pigment structures, the elasticity of coatings depends on the type of binders used in the coating.

<u>BINDERS</u>

The purpose of the binder is to cement the pigment particles firmly to the paper surface and to each other. Binders are used at the lowest level consistent with the end use requirements of the product.(8 p.287) If too much binder is used, the voids in the coating structure begin to fill in and light scattering ability is lost. The binder must be compatible with the other ingredients in the formulation, they are used to stabilize the pigment, and offer some control of the flow behavior. During the actual coating process, the binder offers additional properties such as water retention, response to high shear, leveling, binder migration, and drying rate. They also affect many of the final properties, with glossing response being one of them. The two binders chosen were SBR and PVAC. Both of these binders are latex polymers. They were chosen because one chief advantage of latex binders is their improved response to gloss when compared to other binders. While the binders are both latex, the final properties and advantages of both types are quite different. The advantages of SBR are good bonding strength, good gloss ink holdout, good gloss, and low specific gravity. The advantages of PVAC are excellent brightness stability, good stiffness, very porous, and good blister resistance. (4 p.65) Along with these different properties, there are also disadvantages of each binder. A compromise of the advantages and disadvantages will be met in the amount of binder used.

GLOSS

Gloss is the ratio of specularly reflected light to incident light. The Tappi test method T 480 describes the specular gloss of paper at 75 degrees. The chief application of this gloss measurement is used for coated papers.(9) This method is widely used as a measure of surface quality and shiny appearance of coated paper. The gloss meter itself consists of a light source, a lens giving a converging beam of rays incident to the test specimen, a suction plate to hold the specimen flat, and a light detector to receive and measure certain of the rays reflected by the test specimen.

In the case of clays, the gloss increases in direct relation to the fineness of the particle size. The effect of calendering is not so exact due to the difficulty in applying equal calendering treatments to all test samples. In general, sheets with high uncalendered gloss will tend to give higher calendered gloss values.(3 p.81) There is a limit to the amount of calendering that can be done before gloss and other properties decrease, and this threshold should not be surpassed. Aside from the particles size, there are many factors that contribute or affect gloss. Some of them are types of binder used, intensity of calendering, binder ratio, sheet roughness, viscosity of the coating color, and many others.

Gloss is a function of roughness, and can be used to characterize surface roughness. With coated paper, the substrate contributes a macroscopical roughness that has an order of magnitude higher than the microscopical roughness of the coating. (10 p.13) The gloss of coated papers increases with coat weight as macroscopic roughness decreases to reach a level off value correlating to the optical roughness. Increasing the addition of binder always brought about a continuous decrease in the gloss of the coating until the critical pigment volume concentration was met. The rate at which this occurs depends on the binder type.

There are many factors which influence the gloss of the coated sheet. Once the sheet is printed, the number of variables that effect the print gloss become even more compounded. The print gloss is measured in the same manner, however, it must be noted that print gloss is usually measured at 20 degrees and not 15 degrees as in the case of coatings. This is done in order to obtain a higher gloss value since the print gloss is normally lower than the coated gloss unless very high gloss inks are used. The coated gloss and print gloss were measured at the same angles in order to obtain a value of delta gloss. The effect of the pigments and binders on print and delta gloss was one of the objectives. Print gloss is affected by the coating structure, printing conditions, the types of ink used, and the ink level used.(1 p.154)

COATING RHEOLOGY

In the coating process, the coating formulation is subject to a wide range of shear rates. These shear rates range from simple pumping of the coating to use on a high speed coater. In general, the rheological properties of a coating must be observed and controlled in order to be able to run the formulation on a high speed coater.(11 p.51) The rheology is highly influenced by interaction between pigment and binder. Therefore, an understanding of the internal structure of the coating color at different shear rates is of major importance when the influence of different binders on the coating performance is examined. The viscoelasticity measurements are used to determine interactions between different components in the coating color in order to study the results in formation of structures in the wet state. The viscoelasticity measurements provide information about the strength of the structure formed. These properties are important since the structures are subjected to very significant stresses during the coating process.(12 p.235)

CLC

The Cylindrical Laboratory Coater (CLC) is a high speed laboratory coater which promotes low cost research and experimentation into coated paper improvements, new product development, and coating rheology. The CLC helps predict the coating performance at actual high shears, thus relating very well with conditions on a mill size coater. (13 p.81) Weyerhaeuser constructed this state of the art high speed laboratory blade coater to meet the coating development needs. The CLC has the ability to coat at speeds up to 4000 fpm. The coated samples are large enough for laboratory supercalendering, paper physical testing, and laboratory print testing. The machine makes use of IR preheating of the paper and IR drying of the coating. It contains programmable drying cycles with independent intensity and exposure time. It offers blade pressure adjustments for the ability to make coat weight changes. It is fully automated and can be run with only one operator. The CLC is a reliable, repeatable, and flexible high speed laboratory blade coater. It is a useful tool in predicting coating performance characteristics prior to production trials.(13 p.87)

METHODOLOGY and EXPERIMENTAL DESIGN

The first step is to make the eight different coating formulations that will be run on the CLC. These coatings will vary in pigment and binder type. The four pigments used are #2 clay(100%), $CaCO_3$ (100%), delaminated clay (25% substitution), and calcined clay (15% substitution). The two different binders used will be SBR and PVAC. Approximately 1 liter of each coating color will be made in order to run on the CLC. These eight coatings will be run on the CLC at medium and high coat weights, therefore, a total of 16 coatings will be run on the CLC. The final solids levels of all the coatings will be targeted for 62%. The coatings were prepared and the low shear viscosity (Brookfield) was adjusted to within the same ranges (about 1500 cp) using ALCO gum or polyacrylate. The pH was then adjusted using 10% NaOH solution for proper runnability on the CLC. Brookfield viscosity curves were run on all the coatings in order to compare the low shear viscosities. The coatings were then run on the CLC and at this time the Hercules (high shear) viscosity was tested and rheograms were produced.

The coated paper was then tested for a variety of properties. These properties include coat weight, gloss, Parker Print Surf Roughness, brightness, and opacity. The samples were then calendered through four nips at 40 psi(g), and tested again. All these samples were then printed using a print roller and were then tested for print gloss and delta gloss. Initially, the Vandercook proof press and the Moser rotogravure press were going to be used but both machines were disfunctional. The method of printing, however, was very representative. It applied a uniform ink film which was ideal for measuring the print gloss. The ink used was a low viscosity water based flexographic ink. By isolating the ink, the ink levels, and printing method used, a good correlation of how the pigments and binders affected the gloss, print gloss, and delta gloss values can be obtained. The effects of calendering and coat weight on gloss, print gloss, and delta gloss will also be examined.

RESULTS and DISCUSSION

The results of the testing can be found in Appendices I and II. The results were analyzed and will be shown in figures. The discussion of these figures and charts will follow. The coated sheets were tested for Parker Print Surf Roughness and the results can be found in Figure 1. The roughness of the coated surface has a direct relationship on the gloss response of the sheet. The trend shows this relationship very clearly. The calendered gloss is seen to be higher than the print gloss. This was expected and planned in order to concentrate on the effects the pigment and binder had on the gloss response of the sheet. For this reason, a low viscosity water based flexographic ink was used to print the samples. If a high gloss ink was used it would have negated the effects of the coating structure.

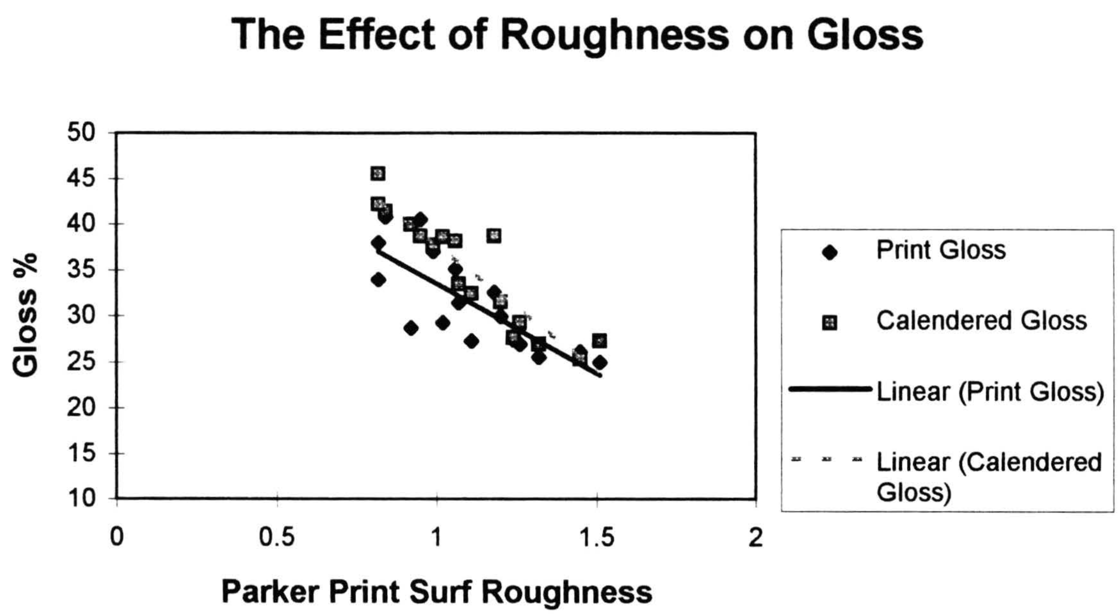

Figure 1. The Effect of Roughness on Calendered and Print Gloss

The coat weight had a direct relationship on increasing the gloss. The results showed that for all coating formulations the increase in coat weight produced on the average a 10% increase in gloss. The medium coat weight was targeted for 10 g/m^2 and the high coat weight was targeted at 15 g/m^2. The #2 clay - SBR formulation was run at low, medium, and high coat weight in order to examine more closely the effect of coat weight. The results can be seen in Figure 2.

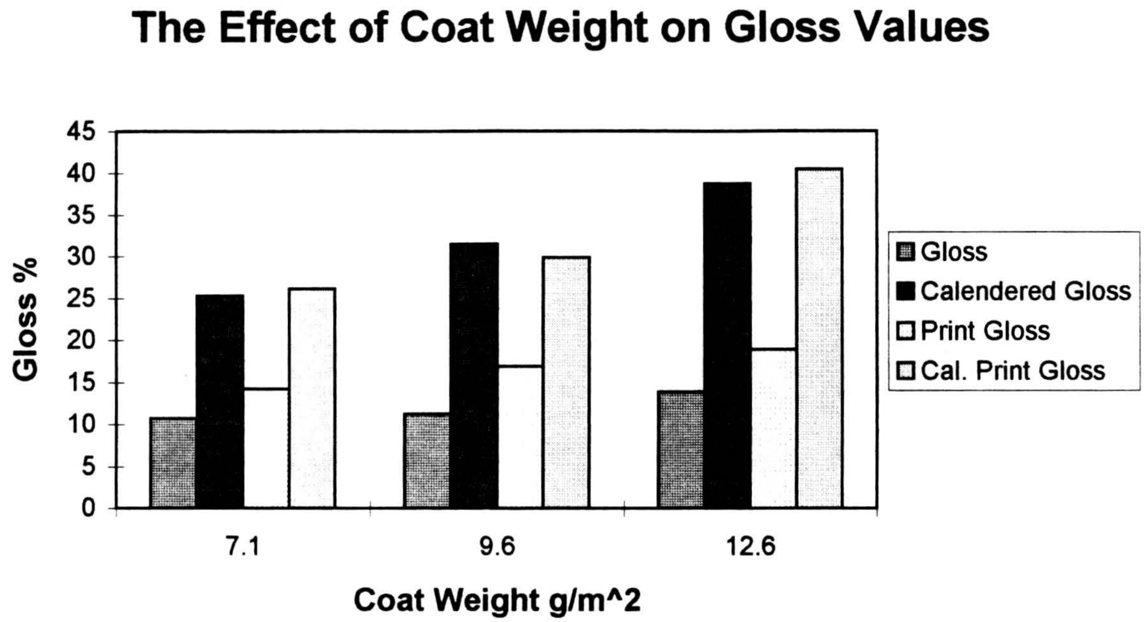

Figure 2. The Effect of Coat Weight on Gloss Values

It was stated in the literature that the gloss should increase proportionally with the coat weight upto a maximum. This point is were complete fiber coverage is achieved and the addition of more coating will not significantly increase the gloss further. (1)

The effect of pigment type using SBR as the binder was examined and the results can be seen in Figure 3. This graph shows the effects that calendering had on the gloss values also. From the graph, it shows that the calcined clay gave the highest gloss values.

This was not expected due to the fact that the particle size of the calcined clay is larger than the other pigments.(3) This demonstrates that the interaction with the binder plays a major role in determining the gloss of a coated sheet. Notice the direct relationship between the incoming gloss and the calendered gloss.

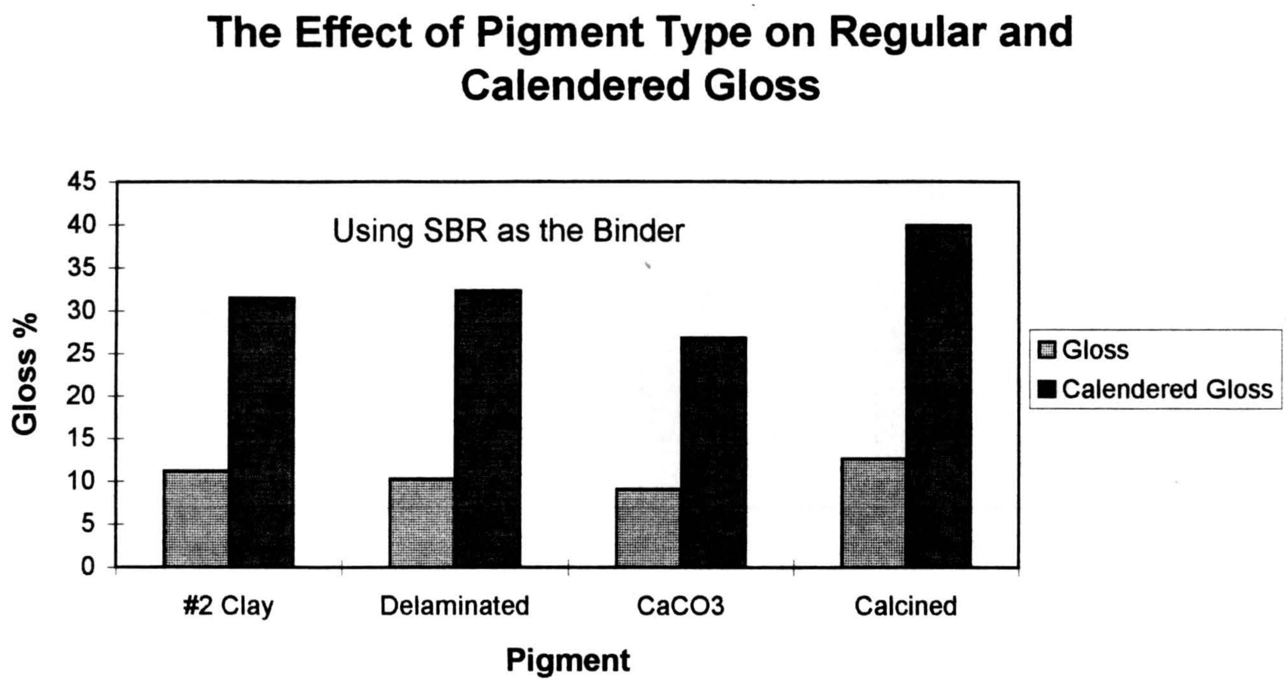

Figure 3. The Effect of Pigment Type on Regular and Calendered Gloss

The same effect was seen at both coat weights, but since the high coat weight optimized the gloss, these values are displayed here.

Figure 4 shows the effect of pigment type on the print gloss. This was done using the SBR binder. The calcined clay displayed the highest gloss value but notice the drop in the print gloss. Here the large particle size of the calcined clay seemed to effect the gloss of the printed image. The drop from gloss to print gloss was 15.5% for the calcined clay. The #2 clay showed an actual increase in print gloss. This was not expected, but the smaller particles of the #2 clay using SBR latex produced an excellent print image. It is stated that the largest contribution of a pigment towards gloss is the percentage of particles finer than 2 microns.(3)

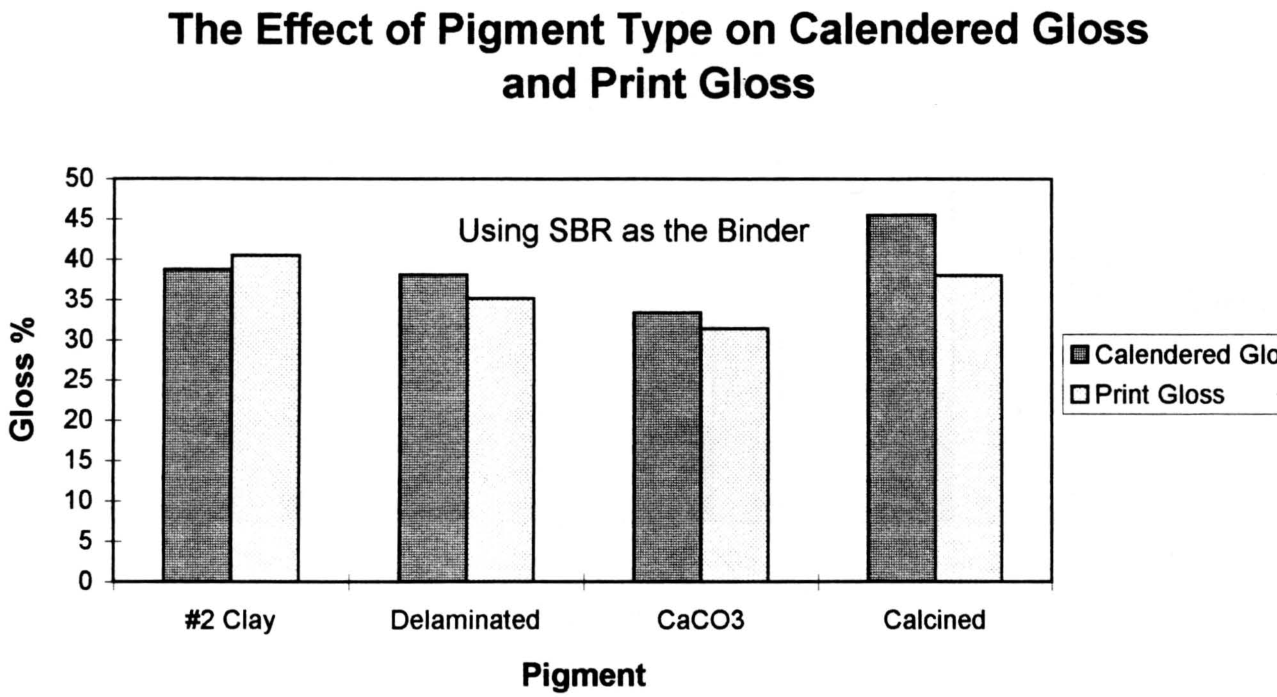

Figure 4. The Effect of Pigment Type on Calendered and Print Gloss

The effect of pigment type on gloss was again examined, this time the PVAC was used as the binder. Once again, the effects of calendering can be seen. The results differed from those using the SBR binder. The delaminated clay showed a great response when using the PVAC as the binder. These results can be seen in Figure 5. The delaminated clay was expected to give higher gloss values due to the structure of this type of clay. (5) This effect was more pronounced at the higher coat weight, this same effect would have been seen at the lower coat weight if a higher substitution level was used. Figure 6 shows the effect of pigment on print gloss. Notice the low delta gloss value of the delaminated clay. Once again, the calcined clay showed very good calendered gloss but had an extremely high delta gloss.

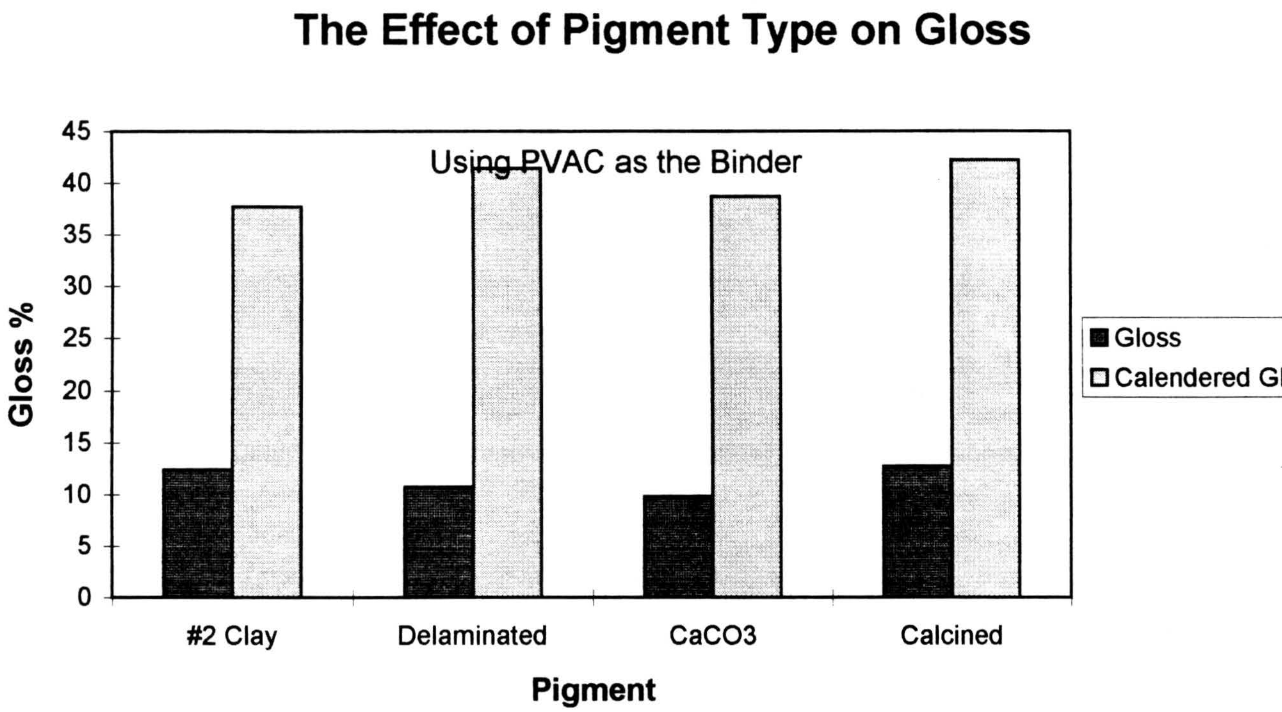

Figure 5. The Effect of Pigment Type on Gloss

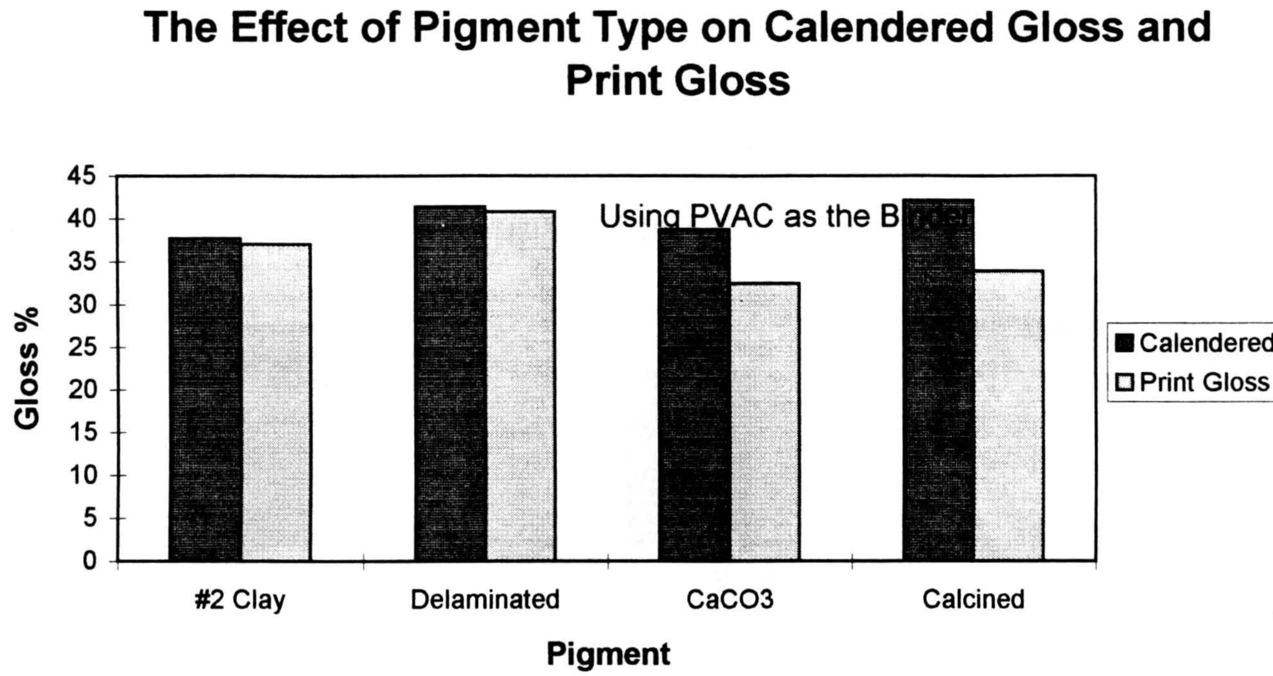

Figure 6. The Effect of Pigment Type on Calendered and Print Gloss

Next the effect of binder type was examined by comparing the data using the same pigment. When using the #2 clay, the SBR latex proved to be the better binder as far as gloss response was concerned. This was expected because one of the chief advantages of SBR is its glossing response when used in coatings.(4) The same effect was seen at both medium and high coat weights. The effect was more pronounced at the higher coat weight, and since this provided the optimum gloss levels for both binders these results are shown in Figure 7.

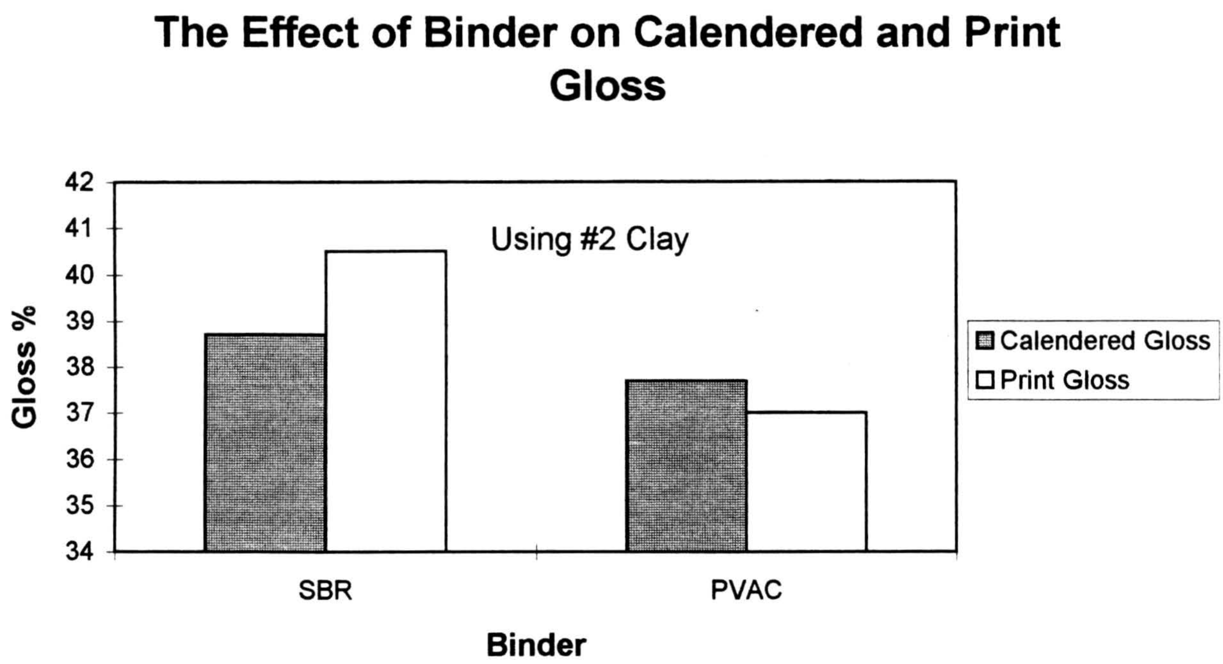

Figure 7. The Effect of Binder Type on Calendered and Print Gloss

The effect of binder type had a different result on gloss and print gloss when using delaminated clay. The results can be seen in Figure 8. Here the PVAC gave a better gloss response than did the SBR latex. An increase in 17.1% was seen when using the PVAC as the binder. PVAC has many advantages when used in coatings, but glossing response is not listed as one of them.(4) The interaction between pigment and binder appears to be better for delaminated clay and PVAC. The flatness of the delaminated clay appeared to negate the effect of the smaller SBR particle, thus not allowing them to contribute to the surface smoothness.

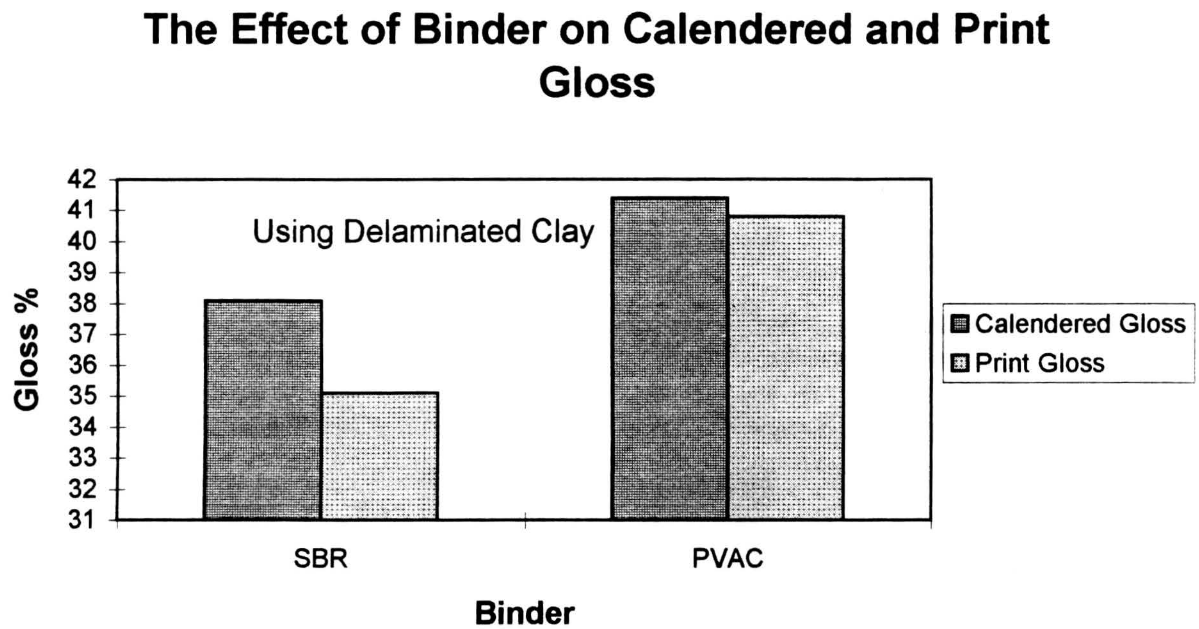

Figure 8. The Effect of Binder Type on Calendered and Print Gloss

The effects of pigment type on delta gloss can be seen in Figure 9. This shows the results when using SBR as the binder. The large drop in gloss when using calcined clay can be seen. This shows that the larger calcined clay particle size reduces the gloss of the printed image far more than the other pigments. The results are different when using PVAC as the binder. This is shown in Figure 10. The calcined clay again showed poor delta gloss, but the delaminated clay showed almost zero delta gloss. These two graphs show the importance of pigment to binder particle interaction. This shows the complexity of a coating structure. These formulations were kept as simple as possible in order to isolate the effects of the pigment and binder.

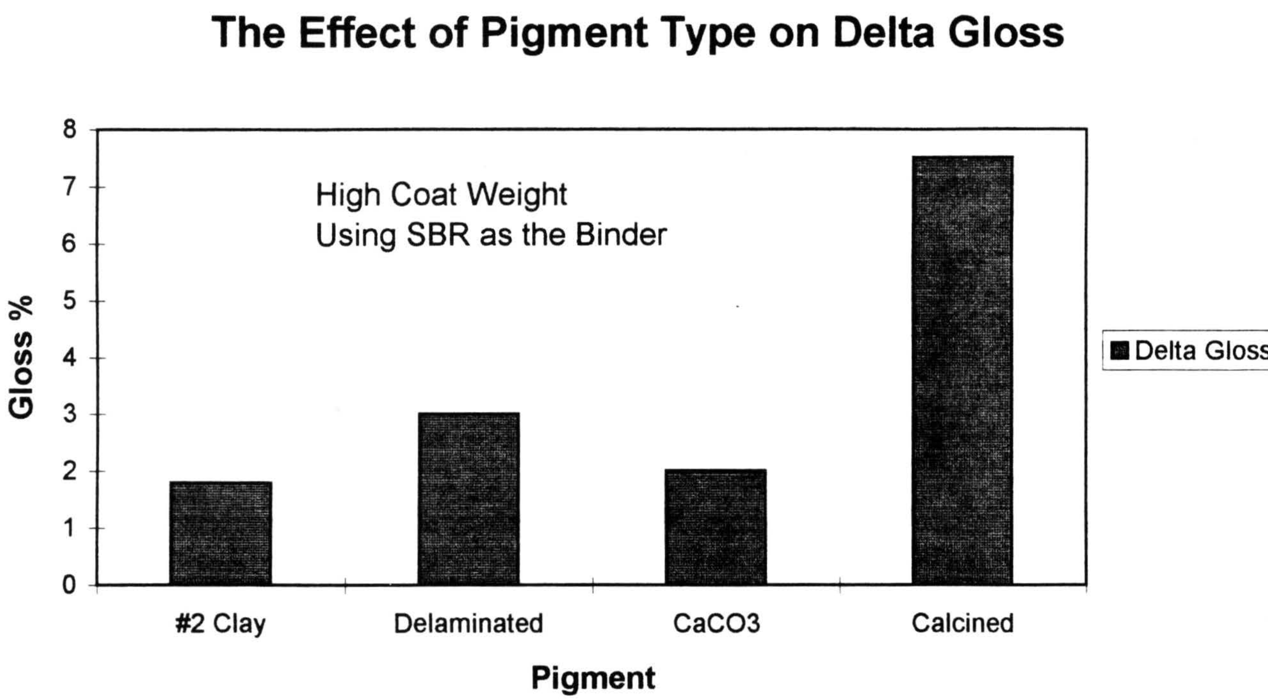

Figure 9. The Effect of Pigment Type on Delta Gloss

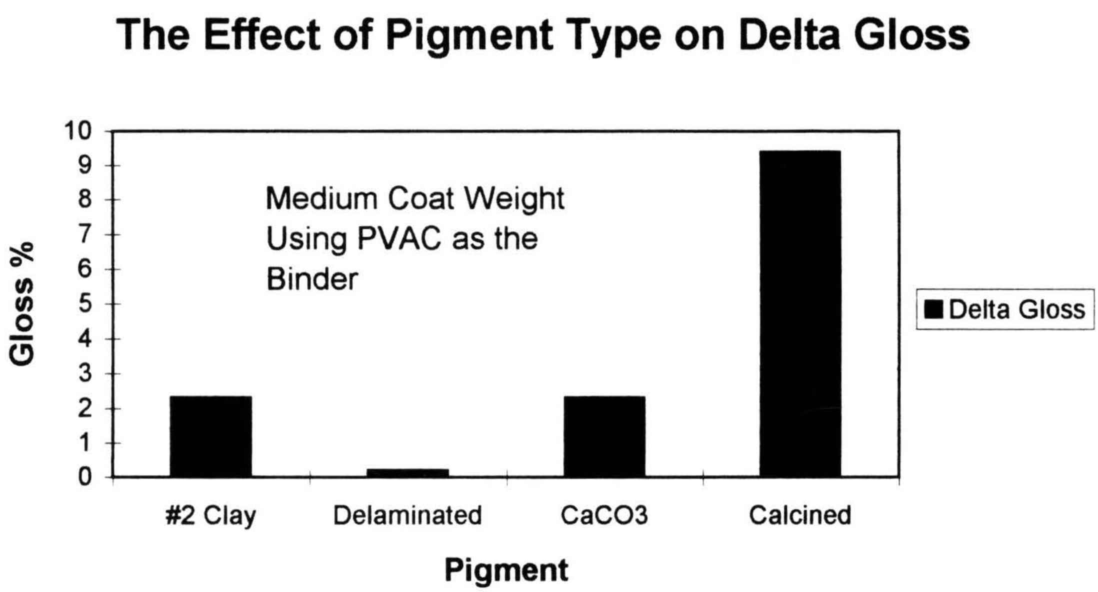

Figure 10. The Effect of Pigment Type on Delta Gloss

The supplemental tests such as brightness and opacity were performed in order to make a comparison of the coatings. While the focus of this study was glossing response, many other properties of the coated sheet determine the quality. The results can be seen in Appendix I. The opacity results for all of the formulations were within 2% of each other. The brightness values were comparable with the calcium carbonate formulation displaying about 5 points higher brightness. This was expected.

Many of the variables were maintained as constants or within the same range. For example, the binder ratio was held constant for all coating colors at 12% based on dry pigment. The solids level was held constant at 62% and the pH was adjusted between 8.0 and 8.5 for good runnability on the CLC. The Brookfield viscosities were adjusted within the same range of around 1500 cp using polyacrylate or Alcogum. The printing conditions were held constant and the same ink was used. Slow print speeds were chosen to negate the effects of the absorbency of the coating. The binder addition level greatly affects the absorbency of the coating, but it was proven that at slow print speeds the print gloss is not affected by the coating absorbency. (1) These variables were held constant in order to isolate the effect of the pigment and binder.

CONCLUSIONS

A coat weight increase of 5 g/m^2 gave an average increase in coated gloss of 10%, and gave a 20% increase in calendered gloss. The delaminated clay using the PVAC as the binder showed the highest gloss response due to an increase in the coat weight. At the higher coat weight a 33% increase in gloss was achieved.

Calendering the sheet improved all values of gloss dramatically. This was expected and the trend held true for all coating formulations. The effects were greater for coated gloss than for the print gloss. This was desired because it shows that the gloss of the ink itself did not play a role in the gloss values rather it was the surface structure of the coating that determined the gloss response.

The effects of the pigment and binder type varied depending upon the combination. The calcined clay gave the best calendered gloss which was not expected. The particle size of calcined clay is larger than the #2 clay, therefore, the gloss should be higher. The binder to pigment interaction played a severe role in the gloss response. The calcined clay did show the worst delta gloss. When using PVAC as the binder, delaminated clay displayed the best print gloss and lowest delta gloss. When using SBR, the #2 clay gave the best print gloss properties. This shows the importance of the pigment-binder particle interaction.

RECOMMENDATIONS

Further study could be performed in this area in a number of ways. With the demand for high quality coated paper and the concerns of printability, the need to utilize both the Paper and the Printing departments for thesis work should be employed. There is potential to branch off this study for other students.

By concentrating on one binder and optimizing the addition level or binder ratio, the optimum addition level could be found

The type of pigment could be isolated and optimum substitution rates could be examined. This could be done using delaminated clay or any type of pigment.

Different printing methods could be used along with different types of inks. The effect of solvent based ink should be looked at as well as printing at different speeds.

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APPENDIX I

Pigment	Binder	Coat Weight g/m^2	Gloss Regular	Gloss Calendered	Print Gloss Regular	Print Gloss Calendered	Delta Gloss Regular	Delta Gloss Calendered
#2 Clay	SBR	7.1	10.7	25.3	14.2	26.1	3.5	0.8
#2 Clay	SBR	9.6	11.2	31.5	16.9	29.9	5.7	1.6
#2 Clay	SBR	12.6	13.8	38.7	18.9	40.5	5.1	1.8
#2 Clay	PVAC	7.8	11.4	29.2	15.2	26.9	3.8	2.3
#2 Clay	PVAC	13.6	12.4	37.7	16.6	37	4.2	0.7
Delaminate	SBR	9.7	10.3	32.4	13.4	27.3	3.1	5.1
Delaminate	SBR	12.8	11.6	38.1	16.5	35.1	4.9	3
Delaminate	PVAC	9	9.4	27.6	14.7	27.4	5.3	0.2
Delaminate	PVAC	16	10.7	41.4	18.2	40.8	7.5	0.6
CaCO3	SBR	8	9.1	26.9	12	25.5	2.9	1.4
CaCO3	SBR	14.7	10.6	33.4	15.4	31.4	4.8	2
CaCO3	PVAC	12.2	9.5	27.3	11.5	25	2	2.3
CaCO3	PVAC	17.5	9.8	38.7	11.3	32.5	1.5	6.2
Calcined	SBR	11.3	12.6	39.9	15.6	28.7	3	11.2
Calcined	SBR	15.3	14.4	45.5	16.1	38	1.7	7.5
Calcined	PVAC	10.4	11.5	38.6	11.9	29.2	0.4	9.4
Calcined	PVAC	15.5	12.7	42.2	14.9	33.9	2.2	8.3

Pigment	Binder	Parker Print Surf Roughness Regular	Parker Print Surf Roughness Calendered	Brightness Regular	Brightness Calendered	Print Opacity Regular	Print Opacity Calendered	Tappi Opacity Regular	Tappi Opacity Calendered
#2 Clay	SBR	2.23	1.45	81.2	80	86.1	84.9	85.6	83.8
#2 Clay	SBR	1.96	1.2	80.9	79.8	87.4	85.9	86.8	84.8
#2 Clay	SBR	1.79	0.95	80.1	78.4	88.5	86.5	87.8	85.3
#2 Clay	PVAC	1.95	1.26	82.2	81.2	86.6	86.2	86.2	85.7
#2 Clay	PVAC	1.76	0.99	81.4	79.9	90.3	88.4	90	87.8
Delaminate	SBR	2.15	1.11	81.1	80.1	86.8	85.9	86.2	85
Delaminate	SBR	1.83	1.06	81.1	79.5	88.9	87.7	88.5	86.8
Delaminate	PVAC	2.06	1.24	81.6	80.9	86.9	85.9	86.3	85.3
Delaminate	PVAC	1.98	0.84	81	79	89.7	88.1	89.3	87.2
CaCO3	SBR	1.86	1.32	86.4	86.2	86.3	85.4	86.7	85.9
CaCO3	SBR	1.78	1.07	87.4	86.9	88.6	87.1	89.2	87.8
CaCO3	PVAC	1.79	1.51	87.4	87.1	87.9	87	88.6	87.6
CaCO3	PVAC	1.87	1.18	88.1	86.4	89.2	86.7	90	87.3
Calcined	SBR	1.78	0.92	82.8	81.4	89	87.4	88.8	86.9
Calcined	SBR	1.5	0.82	82	80.3	89.9	88.9	89.7	88.3
Calcined	PVAC	1.91	1.02	82.7	81.7	89	87.2	88.8	86.8
Calcined	PVAC	1.41	0.82	82.7	81.3	90.4	89	90.3	88.5

Appendix II
Brookfield Viscosity Data

Coating Formulation	Brookfield Viscosity	RPM	Spindle #
#2 Clay - SBR	1080	100	4
	1724	50	
	3420	20	
	5980	10	
#2 Clay - PVAC	1030	100	4
	1636	50	
	3230	20	
	5580	10	
Delaminated Clay - SBR	1010	100	4
	1600	50	
	3130	20	
	5400	10	
Delaminated Clay - PVAC	884	100	4
	1400	50	
	2750	20	
	4720	10	
CaCO3 - SBR	2280	100	5
	3744	50	
	8400	20	
	15640	10	
CaCO3 - PVAC	704	100	4
	1184	50	
	2460	20	
	4340	10	
Calcined Clay - SBR	1020	100	4
	1590	50	
	3080	20	
	5240	10	
Calcined Clay - PVAC	1010	100	4
	1660	50	
	3250	20	
	5640	10	

Appendix III

EXPERIMENTAL DESIGN

Four Pigments

* #2 clay (100%)
* calcined clay (15% substitution)
* delaminated clay (25% substitution)
* calcium carbonate

Two Binders

* SBR (styrene butadiene)
* PVAC (polyvinyl acetate)

A total of eight formulations will be made and run on the CLC, which is a high speed laboratory blade coater. Each formulation will be run at a medium and high coat weight with the targets being 10 g/m^2 and 15 g/m^2 respectively. An extra run at low coat weight was fun for the #2 clay - SBR formulation to further examine the effect of coat weight on gloss response. A total of 17 runs on the CLC were performed